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Morphometric Analysis for Hard Rock Terrain of Upper Ponnaiyar Watershed, Tamilnadu –A GIS Approach

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Abstract: *Morphometric characteristics of a basin represent physical and morphological attributes that are employed in synthesizing its hydrological response. The quantitative analysis of drainage system is an important aspect of characterization of watershed. Using watershed as a basic unit in morphometric analysis is the logical choice because all hydrologic and geomorphic processes occur within the watershed. However, the manual measurement of this parameter is time consuming process. GIS can be very useful computer based decision support tool for integration of voluminous spatial data from different sources, analysis, and display of the result. Arc GIS holds a very large potential in the field of regional and micro level spatial planning particularly in watershed management.The drainage network was delineated using SOI (Survey of India) Topomaps and satellite data of LAND SAT.In our present study the Upper Ponnaiyar river watershed in southern India which extends over 832.85 sq.km, has been selected as the study area. Various linear, aerial and relief aspects of the catchment were computed. Finally, significant characters of the river basin were assessed in the study. From the analysis it can be concluded that the morphometric characteristics indicates low infiltration capacity and high runoff rate in the study area. The study area as a whole shows the classic dentric drainage pattern.*

Keywords: *Quantitative morphometric analysis, Ponnaiyar river basin,Linear aspect,Aerial aspect , Relief aspect,GIS*

1. INTRODUCTION

A watershed is a topographically delineated area drained by a stream system, i.e., the total land area that is drained to some point on a stream or river. A watershed is a hydrological unit that has been described and used as a physical-biological unit and also, on many occasions, as a socio-economic-political unit for planning and management of natural resources (Sheng, 1990)[9].Morphometric analysis is a viable method of characterizing the hydrological response behaviour of the watershed (Debashis chakraborty, 2002)[2]. In the present study, the morphometric analysis for the parameters namely area, perimeter, length of the basin, stream order, stream number, stream length, mean stream length, stream length ratio, drainage density, stream frequency, form factor, circulatory ratio, elongation ratio have been carried out using ArcGIS software and mathematical formulae for computing the morphometric characteristics for various parameters.

2. STUDY AREA

The study area, Upper Ponnaiyar watershed, from part of Krishnagiri and Hosur taluks of Krishnagiri district of Tamilnadu which has been selected for the study lies between 12°30' to 13°00'N latitude and 77°45'E to 78°00'E longitude(Figure 1). It covers a geographical area of 832.85 sq.km and extends a total length of 69.42km.The Ponnaiyar river originates in the Chikkaballapur district of Karnataka at an elevation of about 900m above Mean Sea Level and then flows towards south east direction for a distance of 400 km through Karnataka and Tamilnadu and finally emptying into bay of Bengal at Cuddalore, Tamilnadu state, India. The upper part of the Ponnaiyar basin is covered by the Archaean rocks such as Gneisses, Hornblende Biotite Gneiss, Pyroxene granulites, Quartzite,Ferruginous, Quartzites and Amphibolites.

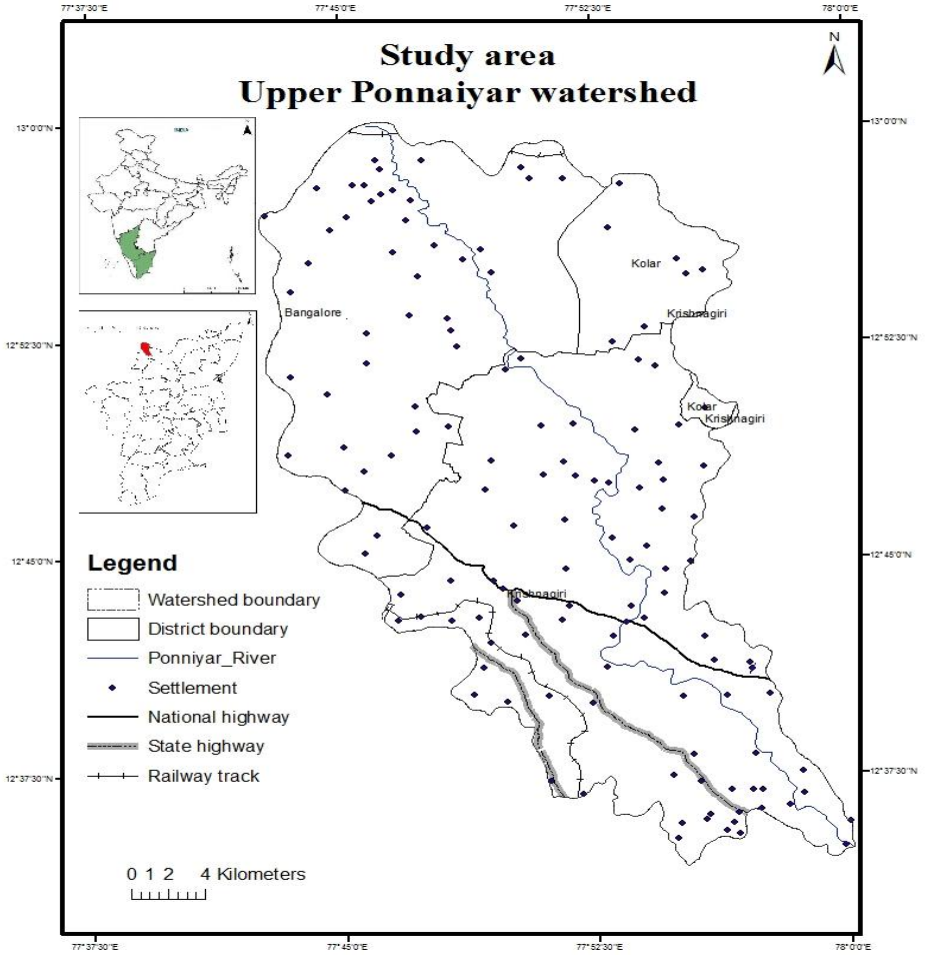

Figure1. *Study Area for Upper Ponnaiyar River watershed*

3. MATERIALS AND METHODS

In the study, SOI Toposheets and satellite images collected from LAND SAT satellite data (1992) were used. The drainage network have been delineated using merged satellite data of geo coded FCC bands of LAND SAT(1992) and SOI Toposheets numbered as reference.Toposheet and satellite image was given as input and toposheet was georeferenced. Streams were digitized using ArcGIS software.The order was given to each stream by following Strahler (1964)[10] stream ordering technique. The attributes were assigned to create the digital data base for drainage layer of the river basin. The map showing drainage pattern in the study area shown in (Fig 2) was prepared after detailed ground truth verification. Various morphometric parameters such as Linear aspects, Aerial aspects and Relief aspects were computed and geomorphic units shape and infiltration capacity of the area was determined using formulae shown in table 1.

Table 1. *Formulae for quantitaive measurment*

Sl.no	Categories	Symbols/ formulae
1	Drainage density(Dd)	Dd =Total length of streams/Area of watershed
2	Stream frequency(Fs)	Fs =Total number of streams/ Area of watershed
3	Texture ratio(T)	T =Total number of first order streams/Perimeter of watershed
4	Elongation ratio (R_e)	$R_e = (2\sqrt{A/\pi})/L_a$: A= Area of watershed,π=3.41,L_a=Length of basin
5	Circularity ratio(R_c)	$R_c = 4x\ \pi\ A/P^2$: A= Area of watershed,π=3.41,L_a=Length of basin
6	Form factor ratio (R_f)	$R_f = A/L_a^2$: A= Area of watershed, L_a^2=Length of basin
7	Relief ratio(R_r)	$R_r = H_b/L_a$: H_b=Basin relief , L_a=Length of basin
8.	Basin relief(B_r)	$B_{r=}$ Vertical distance between the lowest and highest points of watershed

4. RESULT AND DISCUSSION

4.1. Linear Aspects

Stream orders, numbers, and stream length: From the table 2, it is clear that the streams were grouped into six orders and the first order streams ranges from 799 to 1. The higher amount streams orders indicate lesser permeability and infiltration. The stream length for each stream orders ranges from 608(First order) to 31 km (Fifth order). Longer lengths of streams are generally indicative of flatter gradients. The total length of stream segments is maximum in first order streams and decreases as the stream order increases. The negative relationship between stream orders and numbers of stream to the respective orders confirm that the catchments have complex terrain and compact bed rock (Nag, 1998)[7].

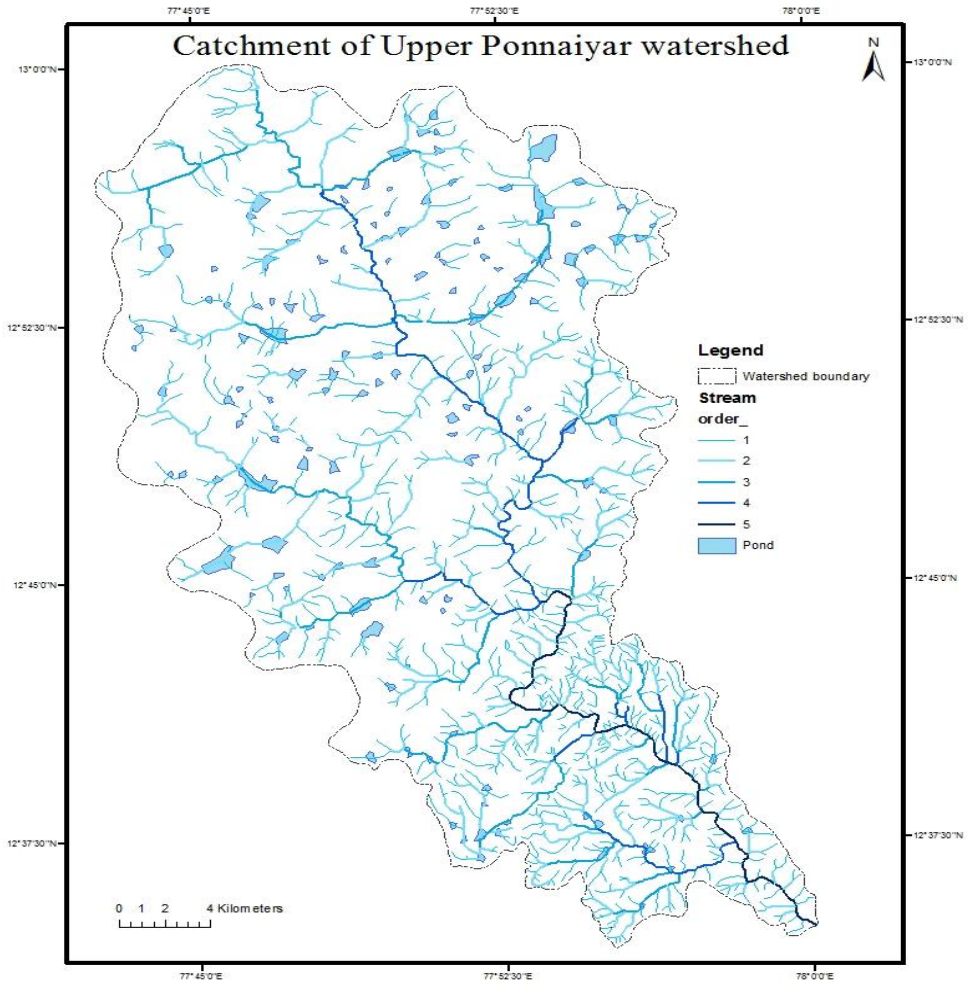

Figure2. *Drainage Pattern of Upper Ponnaiyar River Basin*

4.2. Bifurcation Ratio

Bifurcation ratio is the ratio between the numbers of streams in any given order to the number of streams of next higher order. From table 2, it is observed that medium to high bifercation shows the lithological and structural disturbances on the ongoing drainage development. The high ratio 8 and 8.34 shows the elongated shape of the catchment, higher structural control and high density of lineaments. Ratio between first order and second order stream shows less bifurcation ratio and it indicates less elongation in that area. The first order stream contributes largely in the watershed. The bifurcation ratio of around 2.73 indicates that the stream flow on rocks of uniform resistance to erosion (Debashis chakraborty, 2002)[2].

Table 2. *Morphometric aspects and its results*

Linear aspect Parameters			
Sl.no	Stream order	No. of streams (Nu)	Total length of streams in km (Lu)
1	1	799	608
2	2	292	252
3	3	35	120
4	4	8	60
5	5	1	31
Bifurcation Ratio			
6	1order stream /2 order stream		2.73
7	2 order stream/3 order stream		8.34
8	3 order stream/4 order stream		4.37
9	4 order stream/5 order stream		8.00
Aerial aspect parameters			
10	Area		832.85 km^2
11	Perimeter		168.98 km
12	Drainage density		1.28
13	Stream frequency		1.36
14	Texture ratio		4.72
15	Basin length		69.42
16	Elongation ratio		0.47
17	Circularity ratio		0.0044
18	Form factor ratio		0.17
Relief aspect			
19	Relief ratio		0.001
20	Basin relief		280 m

4.3. Aerial aspects

Perimeter is the length of the boundary of the basin which can be drawn from topographical maps. Basin area is hydrologically important because it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff. It is interesting that the maximum flood discharge per unit area is inversely related to size (Chorley, et al., 1957)[1]. The aerial aspects of the drainage basin such as Drainage density (D), Stream frequency (Fs), Texture ratio (T), Elongation ratio (Re), Circularity ratio (Rc) were calculated and results have been given in Table.

Drainage density(Dd): Drainage density is a measure of the length of the stream segment per unit area (Horton, 1945)[3].Drainage density is one of the prime indicator for selection of artificial recharge sites since it directly indicates the permeability and porosity of the terrain (Krishnamurthy, et al. 2001)[5]. From the table 2, it is observed the drainage density (Dd) was 1.27km/km^2. The high value of the drainage density would indicate an impermeable surface material, sparse vegetation and high run off of the watershed area.

Stream Frequency (Fs): The ratio between total number of streams and area of a watershed is called as stream frequency. Stream frequency discusses the importance to ground water recharge characteristics in a river basin. From table 2, stream frequency was observed as 1.36 in our study area. Its indicates that high runoff on medium to high relief of low permeability.

Texture ratio (T): The ratio between first order stream and perimeter of a watershed is termed as texture ratio. It is a key factor in the drainage morphometric analysis which indicates the underlying lithology, infiltration capacity and relief aspect of the terrain (Reddy, 2002)[8].From table 2, it was observed that 4.72, high ratio indicate low infiltration and complex relief with very low permeability.

Elongation Ratio (Re): is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. The value 0.0 indicates a highly elongated shape and the value 1 is a circular shape (Jawaharaj and Sakthivel, 2012)[4].It is the ratio between diameter of the circle having same area as of the basin and to the length of the same basin.

From table 2, low elongation ratio (0.47) indicates the low infiltration, high runoff and elongated shape of the watershed.

Circularity Ratio (Rc): The dimensional ratio of area of basin to the area of the circle having the same perimeter of the watershed (Miller, 1935)[6].For the basin ranges from 0.4 to 0.5 which indicates that below the indicated range which shows that low permeable geological materials. From the table 2, it is observed that the Circularity Ratio (Rc) of our study area is 0.0044.

4.4. Relief Aspect and Basin Relief

Relief ratio is the ratio between horizontal distance to the vertical distance between same points and it's expressed in terms of gradiant.most of the area covered with nearly gentle sloping. The basin relief of the catchment is varies between 650meters to 930 meters above sea level. From table 2,relief ratio of the basin is 0.001.It clearly shows the low permeability of watershed.

5. CONCLUSION

GIS has proved to be an efficient tool in drainage delineation and this drainage has been used in the present study. According to the order of the stream (strahler order), the drainage is observed to have dentritic pattern. Homogenity in texture on lack of structural control. The mean bifurcation ratio of the basin indicates that the geologic structures are less disturbing the drainage pattern. From the present study the morphometric character indicates that it is less permeable to subsoil, less infiltration capacity and high runoff. Therefore it is necessary to improve the ground water quantity through artificial ground water recharge sits and percolation tanks in the study area.

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